Boeing Ref. 04-0242 (015475)
HDP Ref. 7784-000730

GLOBAL INTERNET PROTOCOL PREFIX NUMBER MOBILITY

FIELD OF THE INVENTION

[0001] The present invention relates generally to the routing of Internet protocol (IP) packets and more specifically to a system and method for routing IP packets to/from a mobile platform where a contiguous network infrastructure may not be available.

BACKGROUND OF THE INVENTION

[0002] Common network routing protocols for the Internet assume that sub-networks each having one or more routers remain fixed or are maintaining a continuous connection to a network architecture. IP packets and necessary routing information are able to be transferred between autonomous systems by first establishing a communications link between at least the sending terminal and the receiving terminal having a plurality of data routers and sub-networks. An Internet routing protocol such as Border Gateway Protocol 4 (BGP-4) can be used to establish communications paths. A preferred routing path can be determined, for example using BGP-4 by assigning various preference attribute values to each available route and selecting the best route in a multi-step process.

[0003] Mobile platforms including for example aircraft, ships, trains, busses, automobiles, etc. (hereinafter referred to for simplicity as aircraft) can encounter difficulties with IP packet transfer because one or more of the sub-networks must either change as the aircraft changes location, or the preferred route must continuously change, which can result in "flapping" as line update messages continuously change as the preferred route changes. One common way to avoid flapping is to "backhaul" all data to the originating sub-network for transfer over the fixed path originally linked. This is often not the most efficient or cost effective way to transfer data.

[0004] United States Patent 6,604,146 to Rempe et al., issued August 5, 2003, discloses a centralized route-server architecture permitting Internet Protocol (IP) services to be offered over satellite mesh networks. The centralized route-server is implemented on a standard workstation. Routing information is

only exchanged between a master terminal and each other terminal in the network. If a connection does not exist to the destination terminal or increased bandwidth is required for the destination terminal, the entry terminal must make a request to the master terminal for a satellite connection or (temporarily) increased bandwidth. If the destination terminal is a moving platform, all routing information must backflow through the master terminal and IP packets are held up pending confirmation of a new route. No allowance is made for an Internet address which changes during a travel segment of a mobile platform.

SUMMARY OF THE INVENTION

[0005] According to a preferred embodiment of the present invention, a global Internet protocol prefix number mobility system operable to link a mobile platform to the Internet includes a ground based communications link manager communicatively linkable to the mobile platform. At least one ground based prefix server is in operable communication with the communications link manager. An initial address is assignable to the mobile platform. A prefix server program is operable to communicate the initial Internet address of the mobile platform to the communications link manager and to the Internet.

[0006] According to yet another preferred embodiment of the present invention a method for maintaining communications contact between a mobile platform and the Internet during a travel segment of the mobile platform using at least one ground based communications link manager includes: creating at least one ground based prefix server operable to communicatively link the mobile platform and the communications link manager; programming the prefix server to operatively select a prefix number for the mobile platform from a plurality of prefix numbers; assigning the prefix number to the mobile platform for the travel segment; and signaling via the prefix server a destination address of the mobile platform using the prefix number communicated via the communications link manager.

[0007] A global Internet protocol prefix number mobility system of the present invention provides several advantages. By locating the prefix server of the present invention adjacent to or within the ground based communications link manager, system hardware or software to perform the functions of the prefix

server can be removed from the mobile platform and positioned in the ground based portion of the flow path to the Internet. This can reduce mobile platform complexity and cost and permit limited numbers of prefix servers to serve a fleet of mobile platforms. By assigning prefix numbers to a mobile platform using a prefix server of the present invention, a local pool of prefix numbers can be retained. The use of a prefix server can reduce the total number of prefixes required to serve the fleet of aircraft by performing prefix management functions. A travel segment for the mobile platform can be provided with Internet access while permitting switching of the prefix number between communications links during travel if necessary.

[0008] The features, functions, and advantages can be achieved independently in various embodiments of the present invention or may be combined in yet other embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The present invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0010] Figure 1 is a diagrammatic view of a global Internet protocol prefix number mobility system according to a preferred embodiment of the present invention;

[0011] Figure 2 is a diagrammatic view showing exemplary Internet system connections for prefix servers of the present invention; and

[0012] Figure 3 is a diagrammatic view showing communication and data flow paths of a mobile routing system according to a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0013] The following description of the preferred embodiments is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

[0014] According to a preferred embodiment of the present invention, and referring generally to Figure 1, a mobile routing system 10 of the present

invention can include a user electronic device 12 positioned on a mobile platform such as an aircraft 14. Internet 16 can be provided with a communication path to user electronic device 12 using a prefix server 18 of the present invention.

[0015] To communicate with the Internet 16, user electronic device 12 can be connected via one or more Internet service providers (ISP) 20 connectable to prefix server 18. Prefix server 18 can be in turn connectable to a ground based communication link manager (GCLM) 22. GCLM 22 can communicate via a two-way communication path 23 to a ground based transmitter/receiver (GBT/R) 24. GBT/R 24 can transmit electronic signals to and from a communications satellite 26 via a signal path 28. These electronic signals can be communicable to an antenna 30 of aircraft 14 via a satellite/aircraft communication path 32. Within aircraft 14 communications signals can be transferred to and from an aircraft data transfer system 34 which can transfer or receive signals to/from user electronic device 12 via a signal path 36. Signal path 36 can be a hard wired signal path or a radio frequency signal path.

[0016] During a travel segment of aircraft 14, herein defined as a flight originating at a point "A" and ending at a point "B", communication between user electronic device 12 and the Internet 16 can be substantially provided by communications satellite 26. During at least a portion of the travel segment, communication path 32 may be interrupted or broken due to inability of antenna 30 to receive or transmit signals to or from communications satellite 26. During this condition, a new communications path can be opened between antenna 30 of aircraft 14 and Internet 16. This can be accomplished by transferring signals to or from antenna 30 and a communication satellite 38 via a satellite/aircraft communication path 40. From communication satellite 38 signals can be transferred to and from a GBT/R 42 via a communication path 44. GBT/R 42 can be in turn connected to a GCLM 46 via a two-way communication path 47. GCLM 46 can be connected to a prefix server 48 which can directly communicate with Internet 16 or alternately can communicate with Internet 16 via one or more Internet service provider(s) 50 (shown in phantom). Either GBT/R 24 or GBT/R 42 can also communicate directly with aircraft 14, for example via a direct communication path 51. Direct communication path 51 can be used for example when aircraft 14 is preparing for take-off or when aircraft 14 has landed.

[0017] Referring generally to Figure 2, an exemplary functional connection to prefix servers of the present invention is illustrated. Prefix server 18 can be connected between GCLM 22 and a route reflector 52 via an internal BGP connection 54. Route reflector 52 can be in turn connected to a router 56 via an internal BGP connection 58. Router 56 can be connected to ISP 20 via an external BGP connection 60. Additional external connection for signals transferred to and from route reflector 52 can be via a router 62 connected to route reflector 52 via an internal BGP connection 64. Communication signals from GCLM 22 can be transferred to or from communications satellite 26 via a first router 66a connected to a modem 84a associated with a GBT/R 86. A second router 66b connected to modem 84b associated with GBT/R 86 can also provide a signal transfer path from GCLM 22 to and from communication satellite 26.

[0018] A second prefix server 68 can transfer communication signals between GCLM 22 and a route reflector 70 via an internal BGP connection 72. A router 74 can be connected to route reflector 70 via an internal BGP connection 76. Router 74 is in turn connectable to ISP 50 via an external BGP connection 78.

[0019] ISP 20 forms a first autonomous system "C". ISP 50 forms a second autonomous system "D". A router 80 can be connected to route reflector 70 via an internal BGP connection 82. Each of the routers and route reflectors identified in Figure 2 are commonly known in the art. Devices 18, 52, 56, 62, 66a, 66b, 68, 70, 74, and 80 can form an autonomous system "E". Each route reflector 52,70 can be cross connected to opposing auxiliary system routers. Connections 60, 78 permit communications between the Internet and the ground based network system. The external BGP connections 60, 78 permit various routes to be formed between the ground based network system, such as autonomous system "E", Internet service providers (20 or 50), and the Internet 16.

[0020] Each of router 62 and router 80 can communicate with modem 84a and modem 84b, respectively. Modem 84a and modem 84b both in turn can communicate with a GBT/R 86. GBT/R 86 can provide an alternate communication path to Internet 16 as commonly known. Modem 84a and

modem 84b are exemplary of a plurality of modems which can be linked to GBT/R 86 from additional autonomous systems (not shown).

[0021] Prefix server 68 can also be connected to a GCLM 88 via an IP traffic tunnel path 90 which may exist within an autonomous system "F". IP tunnel connections are commonly known and can provide global connectivity between individual IP networks.

[0022] Referring generally to Figure 3, basic functions of a prefix server of the present invention are shown. In this example, prefix server 18 can communicate between ISP 20 and aircraft 14. Initially, each aircraft 14 can be provided with an aircraft unique identification number 92. GCLM 22, prefix server 18, route reflector 52, and router 56 can be provided with an autonomous system number 94. When aircraft 14 initiates the travel segment, a prefix number 96 can be selected from one of at least two sources using prefix server 18. Each autonomous system such as autonomous system "E" can be assigned a local pool of prefix numbers. In this example autonomous system "E" is assigned a local pool of prefix numbers 98. Local pool 98 is initially empty and is provided with each of its plurality of prefix numbers generally at the completion of individual travel segments of aircraft 14 or additional aircraft (not shown). Local pool 98 includes a volume allowing a predetermined number or limit of prefix numbers associated with it. If local pool 98 is empty of prefix numbers, prefix server 18 can next search a global pool 100 of prefix numbers. Global pool 100 can provide a plurality of prefix numbers available from a plurality of autonomous systems. After selecting prefix number 96 from either local pool 98 or global pool 100, prefix server 18 can map the prefix number 96 against the unique identification number 92 of aircraft 14 to a local destination address 102 for aircraft 14. Destination address 102 can be subsequently identified by prefix server 18 as an available site to each of the plurality of autonomous systems which form a possible path of communications of data to or from aircraft 14 and Internet 16 via internal BGP connection 54. If two-way communication path 23 is open, a plurality of route data in the form of network layer reachability information (NLRI) 104 can be transmitted to the plurality of autonomous systems via a plurality of route paths. As known in the art, network layer reachability information can include for example information such as "NEXT_HOP",

"UPDATE", "KEEP ALIVE", "LOCAL_PREF", "AS_PATH" and "NOTIFICATION" messages. The plurality of route paths can include a first route path 106, a second route path 108, a third route path 110 connected to Internet 16, and a fourth route path 112 connected to Internet 16. These route paths are exemplary and are indicative of possible route paths for NLRI 104.

[0023] A mobile autonomous system number (MASN) 115 may also be linked to prefix number 96. Prefix server 18 uses the MASN 115 to modify NLRI 104. Some forms of border gateway protocol may require the originating autonomous system number for a prefix to be generally static in nature. MASN 115 provides the prefix server information to modify the AS_PATH to allow for Internet Service Provider 20 to authenticate and authorize the propagation of NLRI information throughout the Internet 16. The use of MASN 115 also allows prefix server 18 to aggregate a plurality of routes within Local Pool 98 to reduce the need to propagate an exact NLRI to the Internet 16 for each prefix number 96. The use of an aggregate NLRI using MASN 115 also provides for the ability to insert a single NLRI covering all routes within Local Pool 98. A single large prefix number may be preferable by some Internet service providers.

[0024] In some cases it may be desirable to modify the assigned prefix number to an aircraft 14. Prefix server 18 can request a new prefix number 114 by first querying local pool 98 and subsequently querying global pool 100 if new prefix number 114 is not available from local pool 98. Similar to prefix number 96, new prefix number 114 can be mapped with unique identification number 92 to form a new destination address 116. Prior to transmission of new destination address 116, each of the open route paths including route paths 106, 108, 110, and 112 are closed by prefix server 18. New destination address 116 is then identified to the various autonomous systems by prefix server 18 and a plurality of new routes (not shown) are subsequently identified by prefix server 18 to transfer NLRI 104 via the newly open routes. Prefix server 18 returns prefix number 96 to either local pool 98 or global pool 100 when new prefix number 114 is withdrawn.

[0025] Upon completion of the travel segment (in this example from point "A" to point "B"), prefix number 96 (if still current) or new prefix number 114 are returned to local pool 98 if local pool 98 has not reached its maximum

volume. If local pool 98 has reached its maximum volume, the prefix number (96 or 114) is returned to global pool 100. Returning prefix numbers as a first priority to local pool 98 reduces the possibility of external "route flapping" by maintaining the prefix numbers for immediate reuse by the associated autonomous system. It is therefore possible for aircraft 14 to reuse the prefix number just returned to local pool 98 upon initiation of a new travel segment, or another aircraft (not shown) can reuse the prefix number from local pool 98, thus reducing the need to pull prefix numbers from global pool 100.

[0026] When GCLM 22 can no longer communicate via two-way communication path 23 to aircraft 14, the handoff process from GCLM 22 to a subsequent GCLM (for example GCLM 46 shown in Figure 1), includes steps in the following order. The GCLM at the new ground station (in this example GCLM 46) can notify GCLM 22 that unique identification number 92 is now available via a new destination address (for example 116). Prefix server 48 can then inject NLRI 104 as new NLRI via an internal BGP connection.. GCLM 22 can then notify prefix server 18 that unique identification number 92 is no longer reachable. Prefix server 18 can then withdraw the original routes for NLRI 104. Border routers (for example routers 74 and 80 shown in Figure 2) can receive the new NLRI from prefix server 48 (or prefix server 68) via IP tunneled connections such as 90. These border routers can announce the new NLRI to other routers (such as routers 56 to autonomous system "C") which reopens the connection for Internet service provider 20 between aircraft 14 and Internet 16.

[0027] On landing the following steps are taken. The active GCLM (GCLM 22, GCLM 46, or GCLM 88) can notify prefix server 18 of the landed status of aircraft 14. Prefix server 18 can return the prefix number (prefix number 96) to either local pool 98 or global pool 100. Prefix server 18 can then notify other prefix servers, such as prefix server 68 shown in Figure 2, that unique identification number 92 mapping is now invalid.

[0028] Prefix servers of the present invention are computer programs performing the functions identified herein. Prefix server programming can be written using existing open source code such as GNU Zebra or other source code. Prefix servers of the present invention are also identified in terms using border gateway protocol 4 (BGP-4). The present invention is not limited to BGP-

4 protocol. Other protocols can be used with modifications inherent to the protocol used which are known to a person of skill in the art.

[0029] A global Internet protocol prefix number mobility routing system of the present invention provides several advantages. By locating prefix servers of the present invention adjacent to or within the ground based communications link manager, system hardware or software performing the functions of the prefix server can be removed from the mobile platform and positioned in the ground based portion of the flow path to the Internet. This can reduce mobile platform complexity and cost and permit limited numbers of prefix servers to serve a fleet of mobile platforms. By assigning prefix numbers to a mobile platform using a prefix server of the present invention, a local pool of prefix numbers can be retained. Retaining these prefix numbers can reduce the potential for external route flapping. A system of the present invention makes use of existing protocols and does not require modifications to existing Internet infrastructure to support prefix number mobility of the system. A prefix server of the present invention acts as an internal BGP route server and a dynamic prefix assignment server. Prefix servers of the present invention are therefore capable of adding routes and setting NLRI data such as NEXT_HOP attributes as well as withdrawing routes when an active GCLM signals that the two-way communication path is no longer available.

[0030] While various preferred embodiments have been described, those skilled in the art will recognize modifications or variations which might be made without departing from the inventive concept. The examples illustrate the invention and are not intended to limit it. Therefore, the description and claims should be interpreted liberally with only such limitation as is necessary in view of the pertinent prior art.